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Implementation of a plus shaped fractal antennas for multi-band applications

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ABSTRACT
Radical changes are taking position in wireless communications technology at a rapid pace to satisfy the current day requirements. Nevertheless the demand for lavishness and mitigated tautness is very much active. An antenna with broader bandwidth, multiband operations, and low profile characteristics are the underlying root of all the modern day demands. Fractal antenna fills this rareness with its unusual attributes of self-similarity and multi-band behavior besides possessing the qualities the features of an ideal antenna. A multi-band antenna can remain applied for operating in more than a single set of frequencies. This singular feature is reinforced using plus shape fractal antenna. This is engaged to supply the needs of the world with its bankable features. Since of its savory properties, it is felt that this report should deal with this fractal type and its cornucopia applications. The main ascendancy of fractal antennas over conventional antennas is shortened the size then multi-band nature. In this paper, the claims and advantages of plus shaped slotted fractal antenna were presented along with their design and radiation properties. It gets its applications in the areas of medicine, military, geology and nevertheless wireless communication. The simulation results are presented using HFSS 13 and verified with a network analyzer.

KEYWORDS: *Fractal, HFSS, self-similarity*

I. INTRODUCTION

In the modern era, man is the alter ego of luxury. A device supporting WLAN, GPS, GPRS, NFC and many more is the demand for the day. If the antenna is applied for each lineament, the size of the desired device wanted be a perpetuity. Also, the hindrances are single band performances of conventional antenna and dependence between size and functioning frequency. Fractal antenna appeared to be the solution aimed at this requirement. A fractal antenna is an antenna with a self-similar figure to enhance the perimeter of the cloth below the issue of electromagnetic radiations within a given total surface area or bulk is named as fractal antenna. The term fractal, derived from "fractals", coined by Mandelbrot, entails breaking or irregular fragments. Radiation characteristics are importantly leveraged by the antenna size about the wavelength. For useful results, the size should be in the order of $\lambda/2$ or larger. However, designing with these parameters would deteriorate the bandwidth, efficiency, and profit. Multiband antenna plays a vibrant part.

II. ADVANCEMENTS & USES

Advantages of fractal antennas are more numerous than those of conventional antennas. The main benefit of the former is its multiband behavior at reduced size. On performing iterations on the basic form, one can obtain increased bandwidth and multi-band nature, contributing to improved VSWR and return losses. The simulated and experimental effects are found to be in full accord. The iteration results obtained are very abundant involved in cellular communications. The self-similarity feature would enhance multi-band and ultra-wide band properties of the transmitting aerial. Shrinking of antenna is possible with space-filling property of the fractal antenna. The generous variety of this antenna spreads from the design of MIC components to contemporary day cellular antennas. It can replace the duck antennas in cellular communication. These antennas are also applied to locate oil, identify geologic faults, and possibly predicting earthquakes. Acid rain and erosion can be established by these antennas. The Spring manufacturing uses the fractal geometry to abate the testing period of strings from 3 days to 3 minutes.

III. FRACTAL CONCEPT

Fractal antenna theory, is an allowance of Euclidian geometry, stems from the classical electromagnetic theory. The main properties of this antenna are self-similarity and space-filling. This self-similar nature enables similar surface current distributions for different frequencies, i.e. multiband behavior is got. By way of space filling property increases the electrical length, slenderized size can be obtained at a desired resonant frequency. In conventional microstrip patch antennas, multiband behavior is accomplished by using multiple radiating elements or reactively loaded patch antennas and the same is possible with self-similarity property in case of fractal antennas. These antennas are basically self-loathing as inductance and capacitance are added without the utilization of any external components and as a result they consist of various resonant frequencies.

Mathematically a fractal is defined based on a fractal dimension given by

$D_s = \frac{\ln(N)}{-\ln(\gamma)}$, where N is the number of copies of entire object and γ is the scaling factor of each copy

IV. TYPES OF FRACTAL ANTENNAS

The various types of fractal antennas are

Hilbert Curve fractal Dipole: Its chief distinctive is the show of lower resonant frequency than any other antenna of the same proportions.

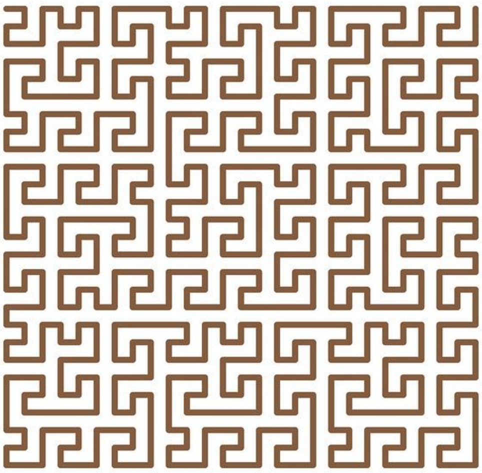

Fig.4.1.Hilber curve Fractal Antenna

4.2 Koch Fractal Monopole: It is a small antenna offering characteristics which no other antenna with the same dimensions could achieve. The fractal dimension of this antenna is log 4/log 3 ≈ 1.26 which is heavier than the dimension of a line but less than Peano's space-filling curve.

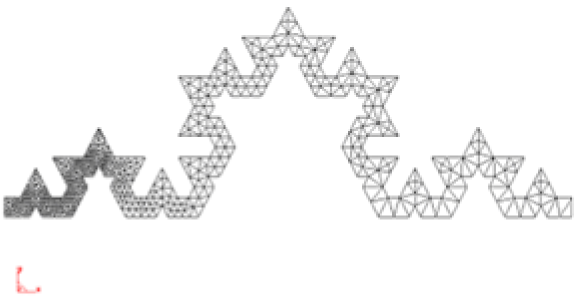

Fig.4.2. Koch Fractal Monopole Antenna

There are also a few other cases like a triangular fractal antenna, plus shape slotted fractal antenna that we are dealing in detail.

TRIANGULAR FRACTAL ANTENNA: The triangular fractal antenna is a good example of a self-similar antenna that shows multi-band behavior. It shows several resonance bands. It has a log-periodic behavior with bands specified by a factor s=2 and with a moderate bandwidth of 21%. The antenna is matched at frequencies: $f_n = 0.26\frac{c}{h} S^n$, where S=2 is log-periodic constant , n is a natural number, c is the speed of light in vacuum and h is the height of largest TFA The stages of expression of a fractal antenna are as indicated in the image. Initially an equilateral triangle and in the next step the center triangle with vertices located at center of the positions of the former triangle are removed. The triangular fractal is generated by holding out this iterative process an infinite number of times.

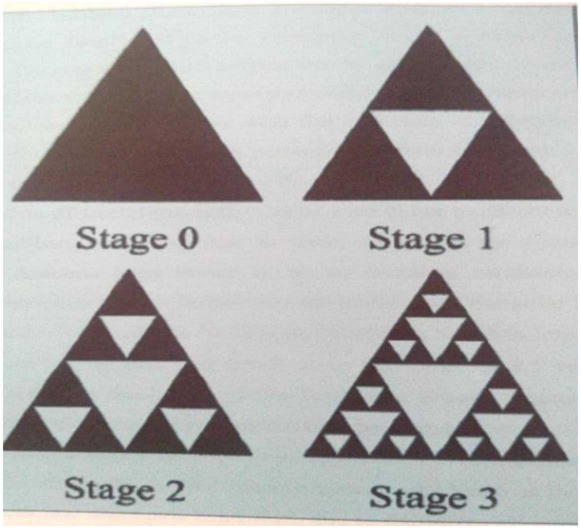

Fig4.3.Triangular fractal antenna

The fractal antenna is envisioned on the FR4 substrate with dielectric constant 4.4 and thickness 1.6millimeter.

$f_r = 0.3 \cos(\alpha) \sqrt{\frac{2.5}{\varepsilon r}\frac{c}{h}} S^n$

Where f_r is a resonant frequency, α is flare angle, ε_r is a relative permittivity of the substrate, h is the height of gasket, S is a scale factor, n is iteration

$l_x = 2h \tan((180-\alpha)/2)$ and $l_1 = l_2 = (h^2 + (a/2)^2)^{1/2}$

Where l_x is length of the edge opposite the flare angle α and l_1, l_2 are the outer edges

In order to calculate the side of the triangular fractal antenna the following parameters are required

$C = 3x10^8$

$\varepsilon^*_{r,dyn}$=4.2 (FR-4)

$L_{eff} = (\sqrt{3}.a)/2$

f_r=2.4 GHz

From the above formulae aimed at resonant frequency, the position of the triangle is calculated as a= 32 mm.

SLOTTED PLUS SHAPE FRACTAL ANTENNA: It is designed based on the fractal concepts for a multiband behavior. A plus shaped patch is removed and is subjected to iterations. Later on each iteration the dimensions decrease to 1/3rd of the base frame. Higher iterations show that the resonant frequencies become lower than those of zero iterations that represent a conventional plus shaped patch. The design specifications are €r=4. 4 and thickness is 1.6mm. The base antenna is equally indicated in the image.

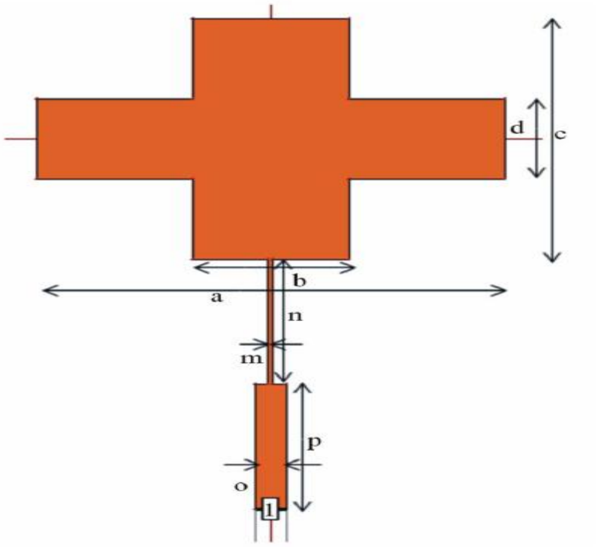

Fig.4. 4.1 1st iteration Plus shaped fractal antenna(PFA)

The first iteration patch is deliberate by four plus shapes of order (1/3) of the improper form are placed touching the foot frame. The same routine is realistic for the iteration 2 where the dimensions are changed as

e = (1/9) a & g = (1/9) c also f = (1/9) b & h = (1/9) d. i = (1/9) e & k = (1/9) g also j = (1/9) f & l = (1/9) h

Where a, b, c and d are the distances and widths of plus shape in base antenna and e, f, g and h are the distances and widths of plus shapes added to the base antenna and my, j, k and l are the distances and breadths of the plus shapes added to the antenna in the second iteration. So with optimized design the dimensions obtained are a = 45.3 mm, b = 15.1 mm, c = 35.4 mm, d = 11.8 mm. The duration of the slot is Ls = 21.675 mm and width of the slot Wise. e. r = 2 mm. The proportion of the ground plan is 55 mm × 85 mm. A 50 ohm SMA connector is utilized to feed the antenna by using microstrip feed technique. Optimized microstrip line with following dimension, m = 0.5 mm, n = 18.55 mm, o = 3.05 mm, p = 18.4 mm. The suitable feed location is received through the optimization process by using the HFSS software.

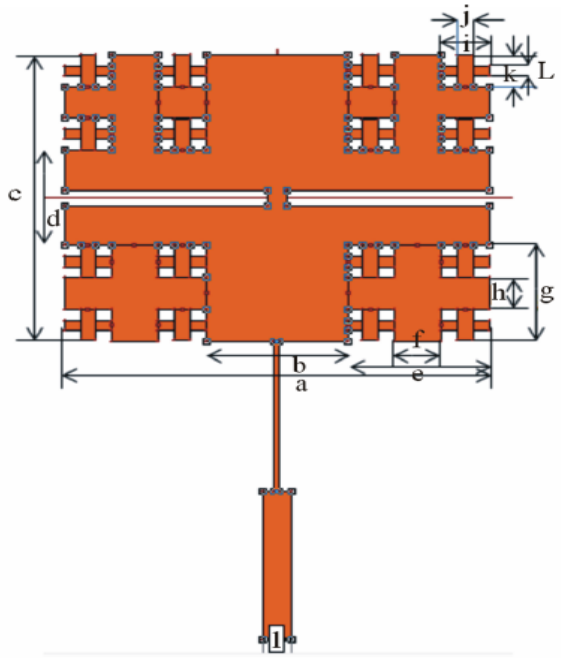

Fig.4.4.2 2nd Iteration PFA

During the first iteration the resonant frequency obtained is 1.27 GHz, which is lower compared to that of 2.199 GHz of the base antenna and when the same antenna is slotted the resonant frequency obtained is 0.99GHz with a phenomenal size reduction of 79.88% and on the second iteration of the same antenna multiple bands are held. It is found that with increasing the slot length starting from the sharpness of the patch, resonant frequency decreases.

V. GENERAL PROCEDURE FOR DESIGN OF MICROSTRIP FED COPLANAR ANTENNA:

Step1: Take any substrate with thickness h and relative dielectric constant ε_r and calculate the width (w1) of the microstrip transmission line for 50 Ω characteristic impedance.

Step2: The width of the center strip (w) calculated using the following equation

$$w = \frac{c}{2f_2\sqrt{\varepsilon_{reff}}}$$

Where

c is the velocity of light and

f_2 is the second resonant frequency.

So the field components are not restricted to the substrate alone the effective dielectric constant) has to be applied instead of relative permittivity of the substratum substrate.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2}$$

Step3:
The distance of the three rectangular strips is then counted as

$$l = \frac{0.15c}{f_1\sqrt{\varepsilon_{reff}}}$$

Where $f_1 = 1^{st}$resonant frequency

Step4:
Width of the lateral conductors (C) is obtained using the equation given below.

$$C = \frac{c}{f_1\sqrt{\varepsilon_{reff}}} - \left(\frac{4l + 2h + w}{2}\right)$$

When h = thickness of the dielectric substrate.

Step5:
Gap separating center strip from the lateral strips is then computed

$$g = \frac{0.014c}{f_1\sqrt{\varepsilon_{reff}}}$$

Where c = velocity of the electromagnetic signal in the free place

Step6:
Ground plane dimensions are calculated using the following equations.

$$w = \frac{0.98c}{f_1\sqrt{\varepsilon_{reff}}}$$

$$L = \frac{0.12c}{f_1\sqrt{\varepsilon_{reff}}}$$

0.12 And 0.98 are the constants that are derived empirically after studying the issue of the ground plane on the two resonant frequencies.

Step7: The two extreme corners of the lateral conductors are connected to the ground plane of the microstrip line using visas or conducting pins.

VI. SIMULATION OF PLUS SHAPED SLOTTED FRACTALLY ANTENNA

Plus shaped slotted fractal antenna (1st iteration) the simulation results obtained on the first iteration are

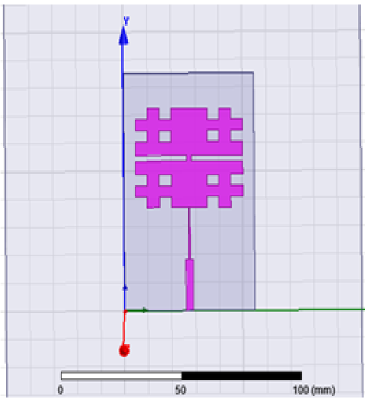

Figure 6.1.1: HFSS pattern of 1st iteration on plotting its response the following graphs are obtained

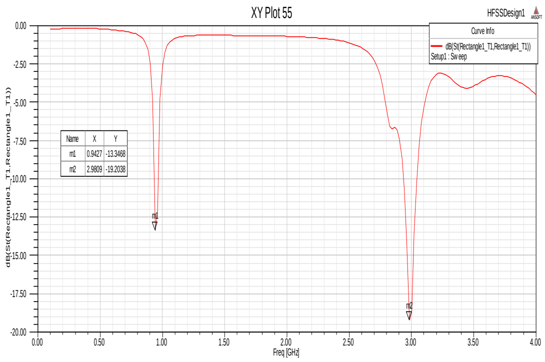

Figure 6.1.2: the Return Loss curve of 1st iteration

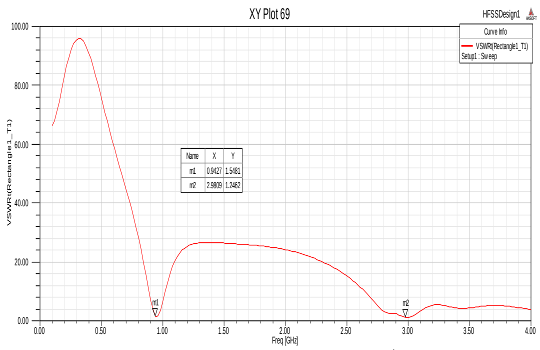

Figure 6.1.3: VSWR curve of 1st iteration

The antenna has resonating frequencies at 0.94GHz and 3GHz, and the return losses are -13.5 and -19 at these frequencies respectively, where the VSWR obtained is between 1 and 2 at both frequencies.

Simiulated Plus shaped slotted fractal antenna (2nditeration). The simulation results obtained on 2nd iteration are

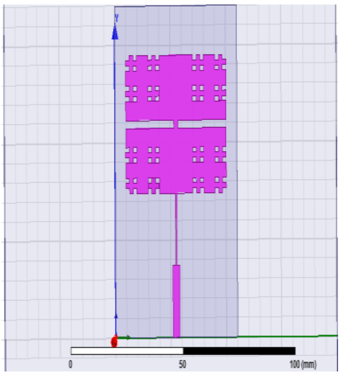

Figure 6.2.1: HFSS pattern of 2nd iteration PFA

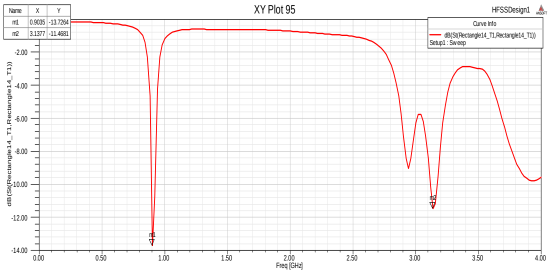

Figure 6.2.2: the Return Loss curve of 2nd iteration

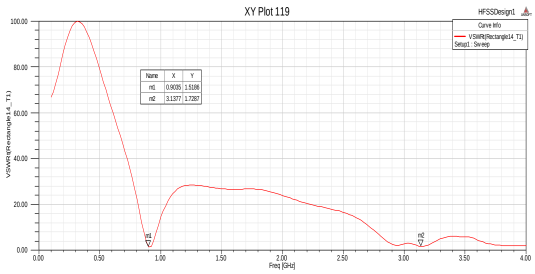

Figure 6.2.3: VSWR curve of 2nd iteration

The antenna resonates at frequencies 0.9GHz and 3.13GHz, which is dual band and the VSWR obtained at these frequencies is found to be between 1 and 2 and the return losses are -13.76 and -11.46 respectively.

The outcomes found when physically tested on a vector network analyzer are

Figure 6.2.4: Fabricated antenna on 2nd iteration

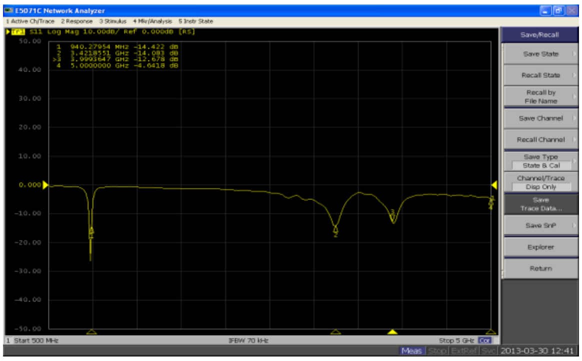

Figure 6.2.5: Return loss curve of the 2nd iteration

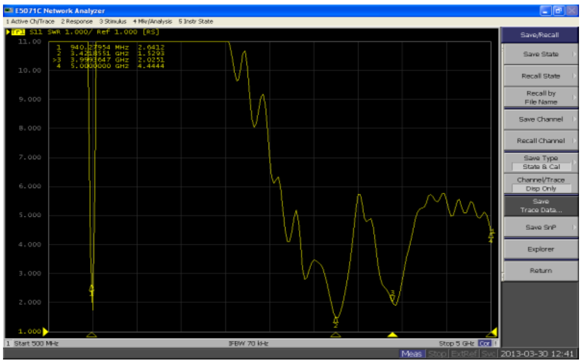

Figure 6.2.6: VSWRcurve of the 2nd iteration

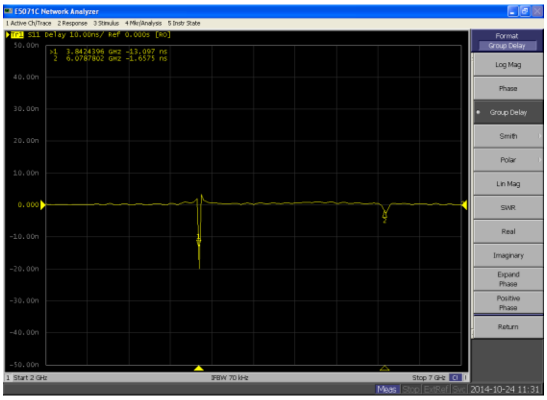

Figure 6.2.7: Group delay curve of the 2nd iteration

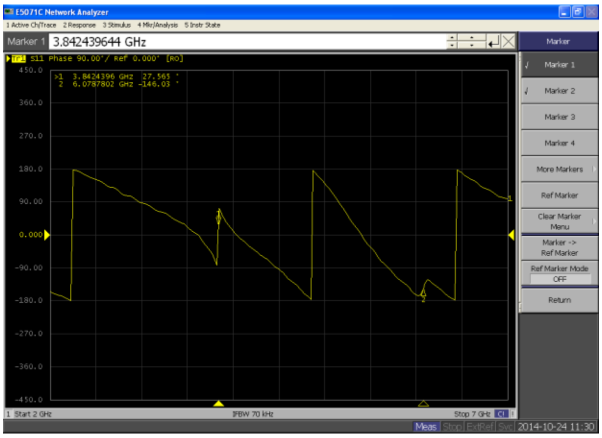

Figure 6.2.8: Phase plot of the 2nd iteration

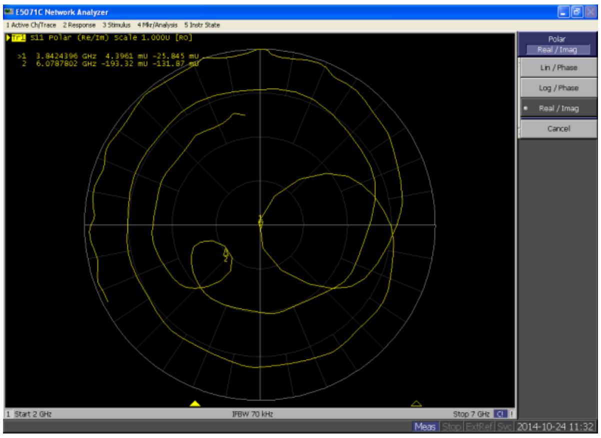

Figure 6.2.9: polar plot of the 2nd iteration

VII. RESULT ANALYSIS

Plus shaped slotted fractal antenna: The PFA acts as a dual band antenna resonated at two different groups 0.94GHz and 3GHz and the experimentation results of 1GHz, 2.94GHz and 3.12GHz. Details of the simulated and experimental results were exhibited below:

Table 9.1: Results obtained for the antennas

S.no	Parameter	Plus the shaped fractal antenna	
		1st iteration	2nd iteration
1.	Return losses at 1st resonant frequency	-13.5db at 0.94GHz	-13.6db at 0.9GHz
2.	Return losses at 2nd resonant frequency	-19db at 3GHz	-11.6db at 3.13GHz
3.	VSWR at 1st resonant frequency	1-2 at 0.94GHz	1-2 at 0.94GHz
4.	VSWR at 2nd resonant frequency	1-2 at 3GHz	1-2 at 3.13GHz
5.	% Bandwidth At 1st resonant frequency	3.53%	3.7%
6.	% Bandwidth at 2nd resonant frequency	3.69%	1.7%

VIII. CONCLUSIONS

As per the simulation and experimental results obtained the proposed plus shaped antenna exhibited the multiband nature, The plus shaped slotted fractal antenna resonated at 0.94 GHz, 3.43GHz and 4GHz on 2nd iteration. Hence, the proposed antennas can find the application in wireless communication systems where size reduction is one of the key factors. Further, the number of iterations are increased to meet the wireless standard requirements. Fractal antennas also decrease the area of a resonant antenna, which could lower the radar cross-section (RCS). These benefits can be exploited in military applications where the RCS of the antenna is a very crucial parameter.

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